Ohio Agricultural Experiment Station

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THE COST OF TILE DRAINAGE

A STUDY OF THE COST OF INSTALLING THIRTY-FIVE MILES OF TILE DRAINS ON A FARM IN HURON COUNTY, OHIO

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The paramount importance of tile drainage to Ohio agriculture is fast becoming manifest to an appreciable percentage of those who should be interested in the subject. Ohio has 19,000,000 acres in improved land in farms and it is probable that it would be a good business proposition to install a thorough system of tile drainage in a large part of this area.

In past years many have thought that the economic use of tile drainage was limited to swamp areas or special low places in fields in which the water naturally accumulated. It is now coming to be recognized, however, that in many cases the higher ground needs the drainage almost, if not quite, as badly as do some of the lower areas.

In a number of bulletins, which have been issued within the past decade, the value of tile drainage has been emphatically pronounced. Some of the points mentioned are as follows:

(a) Tile drainage not only removes the surplus water from the soil, but also increases the amount of moisture available for plants.

(b) The removal of water from the soil in this way tends to diminish the injuries due to surface erosion by keeping the soil in a sponge-like condition ready to receive and retain a liberal rain-fall.

(c) Tile drainage reduces surface evaporation and prevents a consequent lowering of temperature of the soil, thereby having the effect of making it warmer, which in turn promotes plant growth, and lessens the danger of damage by frost, both in the spring and fall.

(d) Tile drainage increases the aeration of the soil, and consequently the bacterial action which increases the available supply of plant foods.

(e) By closing open ditches with tile drains more improved machinery can be used in the preparation of land and the tillage of crops, thus decreasing the cost of such operations.

(f) Land can be plowed earlier in the spring and in better condition, and crops can be cultivated sooner after a rain, thus making a much better distribution of labor on the farm.

(g) Tile drainage promotes a good condition of the soil at time of plowing and consequent ease in preparation of seed bed and cultivation of crop.

It is not however, the purpose of this circular to discuss the need of tile drainage or the method of installing it. For further information regarding these points the reader is referred to Bulletin No. 175, Department of Agriculture, Toronto, Ontario; Bulletin No. 229 of the University of Wisconsin, Madison, Wisconsin; Bulletin 254, Cornell University, Ithaca, New York; special Bulletin 56 Michigan Agricultural College, Lansing Michigan; Bulletin 123 Utah Agricultural College, Logan, Utah, and Farmers Bulletins 187 and 254, U. S. Department of Agriculture, Washington, D. C.

Naturally one of the first questions to be raised in connection with the proposition to install a system of drainage in a given area is "what will it cost?" Not until we have a reasonably accurate answer to this question can we determine finally upon the wisdom of going ahead with the plan. With the hope of contributing somewhat to the answer of this question for Ohio farmers we present in the following pages an approximately accurate record of the expense of the various operations performed in installing 11,395 rods, or more than 35 miles, of tile, which was used to drain areas totaling 228 acres. This work was done in part by hand trenching and in part by machine trenching, thus giving something of an opportunity to compare the two methods.

DESCRIPTION OF SOIL ON THE FARM DRAINED*

Practically all of the soil on this farm is of glacial origin, and has been derived from the drift, which is here composed very largely of pulverized shale. The principal type, called Papakating clay, is a clay loam containing quite a large percentage of silt. The surface soil consists of a pale yellowish or grayish brown clay or heavy silt loam about 9 inches deep, which gradually becomes heavier with depth until at 18 to 24 inches it is a mottled yellow and gray or blue clay, which becomes decidedly plastic at a depth

*Prepared by Dr. George N. Coffey of the Ohio Agricultural Experiment Station.

of 3 feet. The higher elevations, or knobs, which were occasionally encountered, are somewhat lighter in texture, sometimes approaching a sandy loam, and usually contain some large stones or gravel in both soil and subsoil.

The lower lying soil, called Volusia silty clay loam, consists mainly of a dark colored clay loam or clay, varying greatly in depth and underlain by very stiff mottled or bluish clay. This subsoil clay was considered by an expert to be of the right quality for tile making.

Near the centers of the main swamp areas there occur small areas of muck and washed-in material. The deposit of muck is shallow and the soil is is very porous, allowing the water to disappear readily after rains and storms.

The main type of soil on the farm, called Papakating clay, is similar to that on the Experiment Station test farm at Strongsville, and is also similar to quite a larre stretch of country between Norwalk, New London, Lodi and Cleveland. In fact, the greater part of the section of the state just referred to is made up of this type. Some other areas of this soil are found northeast of Alliance, as well as throughout the northeastern part of the state.

It might also be stated that most of the western half of the state is covered by a soil having a texture somewhat similar to that of this farm, although it lies over limestones from which it has been largely derived through glacial action, and is, therefore, somewhat different agriculturally from this type. However, the results deduced from studies on this farm in regard to cost of drainage ought to apply fairly well to that part of the state also, as well as to the section in which this particular type is found. The conditions in the old lake bed in the northwestern part of the state are not so nearly similar and the results would, therefore, be less applicable here than where the conditions are more nearly like those on this farm.

RAINFALL CONDITIONS OF THE AREA DRAINED*

The average rainfall of southeastern Huron County is close to 36 inches, which is slightly more than the rainfall of the Lake counties west of Cuyahoga and more than falls on the average in most of Henry, Putman, Paulding, Van Wert and Mercer counties. It is less, however, than falls in most of the central, southern and eastern counties; the average annual rainfall for the state being 38.9 inches.

During the spring and summer months the average rainfall is between 9 and 10 inches, which is more than falls in the Lake counties, but less than may be expected over two-thirds of the central

*Prepared from Bulletins 235 and 244 of this Station and from notes and information supplied by J. Warren Smith, State Section Director, U. S. Weather Bureau.

and southern district. During the months of June, July and August the total rainfall is close to 11 inches, which is slightly more than may be expected in most of those northern and western counties of the state in which the soil is somewhat similar to Huron county. In the autumn months the precipitation averages between 7 and 8 inches. This is exceeded in the extreme northeastern counties of the state, but it is fairly typical of the northern and western part of the state. In the winter the precipitation is between 7 and 8 inches, which is exceeded in a few of the northwestern counties and in most of the central, southern and eastern counties.

In the year 1909, when the tile drainage work upon the farm under consideration was started, the rainfall there, so far as we can judge from available observation stations, was greater than normal in each of the three months, April, May and June; the total excess for the three months being nearly 1.5 inches. In July, August and September on the other hand, the rainfall averaged slightly less than normal in this section.

In the year 1910 the rainfall here was more than normal in April, September and October. September exceeded the normal by about four inches, and the other two months each had an excess of from two to three inches. The rainfall was below normal each of the other months, being almost two and one-half inches below normal in the month of July.

In 1911 the rainfall was below normal in both May and July almost three inches each month. In September it was just about normal, whereas in April, June, August and October, it was above normal; especially in August, when four inches more than the normal amount of rain fell.

METHODS OF PROCEDURE

The work of installing the tile, the cost of which is given in this circular, was conducted in the field by the Junior author, and all records were kept and compiled by him. The compilation and the manuscript have been checked by Mr. O. E. Brown, who was an assistant on the farm under Mr. Tiffany's management. This work of installation was done in cooperation with the Ohio Experiment Station and the U. S. Department of Agriculture, the regular time blanks of the Department of Cooperation of the Ohio Experiment Station being used (See Fig. 1). The records given herein are quite accurate so far as they go, and for the conditions under which the work was done, but no claim is made that they apply under all soil conditions even in the state of Ohio, as is indicated on preceding pages. We do trust, however, that they will prove quite valuable as a basis of estimate in areas within

which the soil and climatic conditions are similar to those existing in southeastern Huron county, and that they may be of some value elsewhere.

The planning and laying out of the tiling systems in any given field was done by the Farm Manager, usually just previous to starting tiling operations.. In a few instances surveys of the main ditches were made by an engineer to determine the necessary depth of cuts at intervals along the line. Surveys of this kind are especially valuable when a deep cut is to be made. In many instances levels were run on ditches where the amount of fall was doubtful. An ordinary carpenter's spirit level with sights attached was used for this purpose. This method is hardly accurate enough, but on most laterals up to 80 rods in length very good results were obtained. When a main ditch is over 80 rods long and has but little fall the Y level should be used. At the close of the season's operations an engineer was employed to make a plot of the fields tiled, showing the exact locations of all the drains . (See Fig. 2 on page 11).

All ordinary labor, such as hauling of tile, filling of trenches. etc., was done by men and teams taken from the regular force on the farm.

TABLE I. Summary of tiling operations in 1909.

Total rods, 2,560; total area, 40 acres. Man rate, 15c per hour; horse rate, 10c per hour.

	Total labor			Labor per acre			Labor per rod		
	Hours		Cost	Hours		Cost	Hours		Cost
	Man	Horse		Man	Horse		Man	Horse	
Hauling tile	135.5	271	$ 47.42	3.38	6.77	$1.184	.053	.106	$0.0186
[1]Trenching & laying tile	3855.0	...	963.74	96.40	....	24.090	1.500	....	.3760
Filling ditches	305.0	305	76.23	7.62	7.62	1.902	.119	.119	.0300
[2]Other equipment charges	.....	...	10.00	....	....	.250	....	....	.0040
Cost of tile	.....	...	555.39	....	....	13.880	....	....	.2170
Overhead charges	.....	...	58.88	...	....	1.472	....	....	.0230
Plotting drains	.....	...	40.45	....	....	1.010	....	....	.0158
Totals	.....	...	1752.11	....	....	43.788	....	....	.6844

[1]Man rate varied from 20 to 25 cents per hour. The cost is exact, but hours approximate.
[2]Approximate.

EXPLANATIGN OF COST CLASSIFICATIONS FOUND IN TABLES I, II AND III

Of these classifications, figures for machine operator, hauling tile, trenching and laying, laying tile, filling ditches, undivided operations and plotting drains are given in dollars based on the number of hours worked, the cost being obtained by multiplying hours of labor by the rate per hour. Machine charges and other equipment charges include, in addition to labor, cash repairs, interest on investment and depreciation on equipment. The gasoline, oil and cost of tile are straight cash charges and are put in at the actual price paid.

Daily Time Sheet of ..... **Farm.**

In Cooperation with
O. A. E. S. and U. S. D. A.
In Farm Management Investigations.

Make all record on day work is done.

Day of week ..... **Date** .....

Man Hours	Horse No.	Horse Hours	Field	Kind of Work—*Give kind and size of implement used and area covered or amount of work done. When an operation is finished, so state.*
4.30—				
5.00—				
5.30—				
6.00—				
6.30—				
7.00—				
7.30—				
8.00—				
8.30—				
9.00—				
9.30—				
10.00—				
10.30—				
11.00—				
11.30—				
12.00—				
12.30—				
1.00—				
1.30—				
2.00—				
2.30—				
3.00—				
3.30—				
4.00—				
4.30—				
5.00—				
5.30—				
6.00—				
6.30				
7.00—				
7.30—				
8.00—				
8.30—				
—				
Total Hours				.....Workman.

Wage .....
No. Meals .....

Give below kind, amount and value of seed sown, fertilizer used, manure hauled, material used in any operation (such as building fence, etc.) and crop yields (both grain and roughage). Also give source of material, area or portion of field affected and any note regarding weather, crops or stock, which may be of interest or value.

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Made out by .....

Fig. 1. Showing daily time sheet on which the labor records were kept

Overhead charges in this work included only the cost of the actual time of the farm manager to lay out and plan the drainage system and to direct the work in the field. The time required to execute this duty varied considerably from day to day. After the system was once outlined and everything working well it did not ordinarily require more than one or two hours a day.

TILING WORK DONE IN 1909

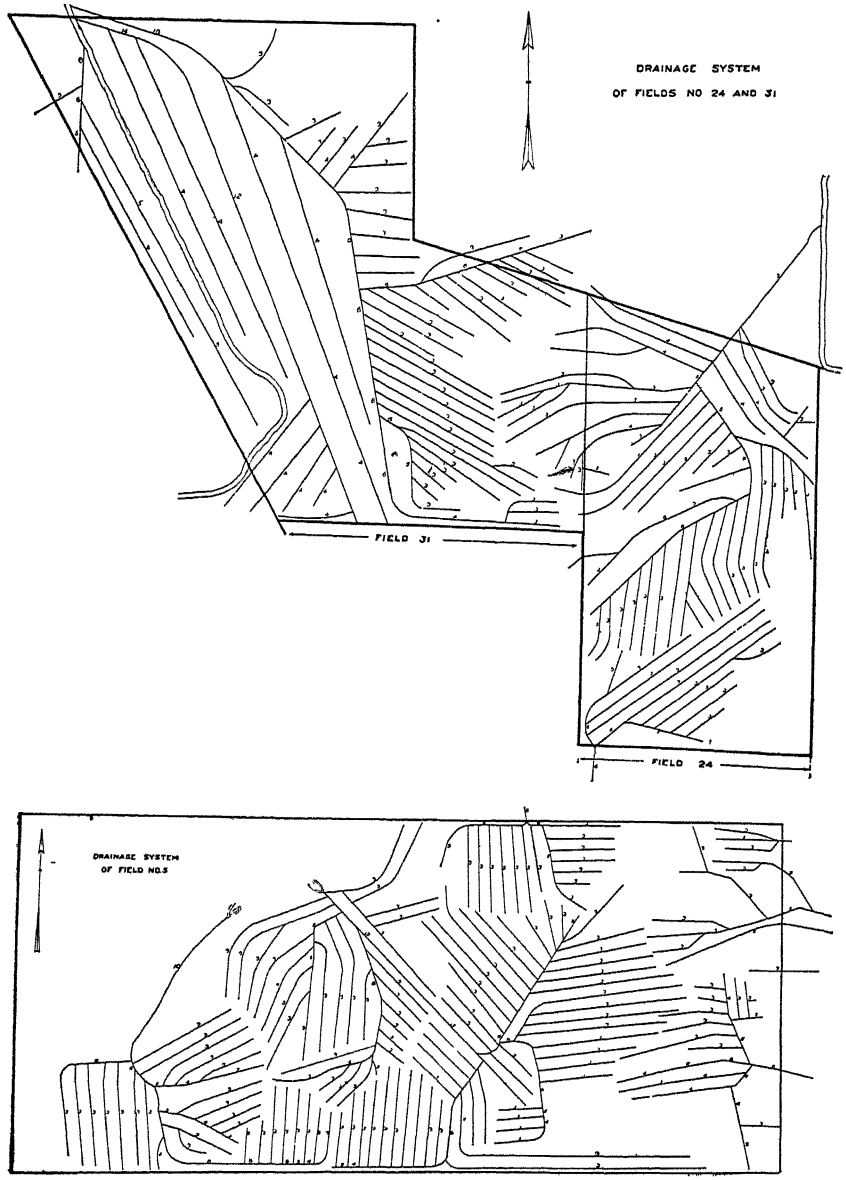
In the season of 1909 the drainage operations were confined to a single field (hereafter designated as No. 2), with the exception of about one-half mile of tiling for which figures are not included in this circular. The outlet for this field, which was an open ditch, had been provided the previous fall.

The surface conditions of this field were somewhat varied. The larger portion of it, or about 30 acres, was upland and quite rolling for this section of the state. The other 10 acres was mostly a clay and muck swamp. On the upland it was comparatively easy to secure a sufficient fall in all ditches, the fall per 100 ft. averaging about 8 inches, but the swamp area the fall would not average over one inch per 100 feet. One main ditch, which was a 12-inch tile, was carried practically on a level for about 800 feet, the grade being determined by the use of water. The condition of the upland portion of this field would be an average for land in that section that had never been worked. It was covered with a heavy bluegrass sod which had been pastured for many years. The ten acres of lowland or of swamp area were covered with bulrushes, cat-tails, swamp brush, trees, etc., and in many instances a clearing had to had to be made before starting a ditch. The cost of this clearing for a ditch was comparatively trivial, however, and is included in the cost of tiling the field.

With the exception of about 160 rods the trenching was all done by hand this year; this 160 rods was dug by a machine rented at an average price of 25c per rod for the trenching alone. This cost of trenching was not deducted and figured separately, but included with the hand dug ditches by using exact figures of cost. Regular workmen employed for spading or trenching were paid from 20c to 22½c per hour for actual time put in. One man of long experience who did the bottoming, grading and laying of the tile received 25c per hour. The distance actually covered by each workman would not average over 8 rods per day under very favorable conditions.

Operations in 1909 were begun in the month of May, and for two months an average of 6 men were employed to dig the trenches. Little work was done, however, during the month of July and early

August because some of the workmen were needed for harvesting and because the ground became so hard and dry. No tiling was done later than October 1st that year. Table I shows a summary of the 1909 tiling operations.



Figs. 2 and 3. Showing copy of engineers map of fields No. 24, 31 and 5

Fig. 4. Rear view of traction ditching machine

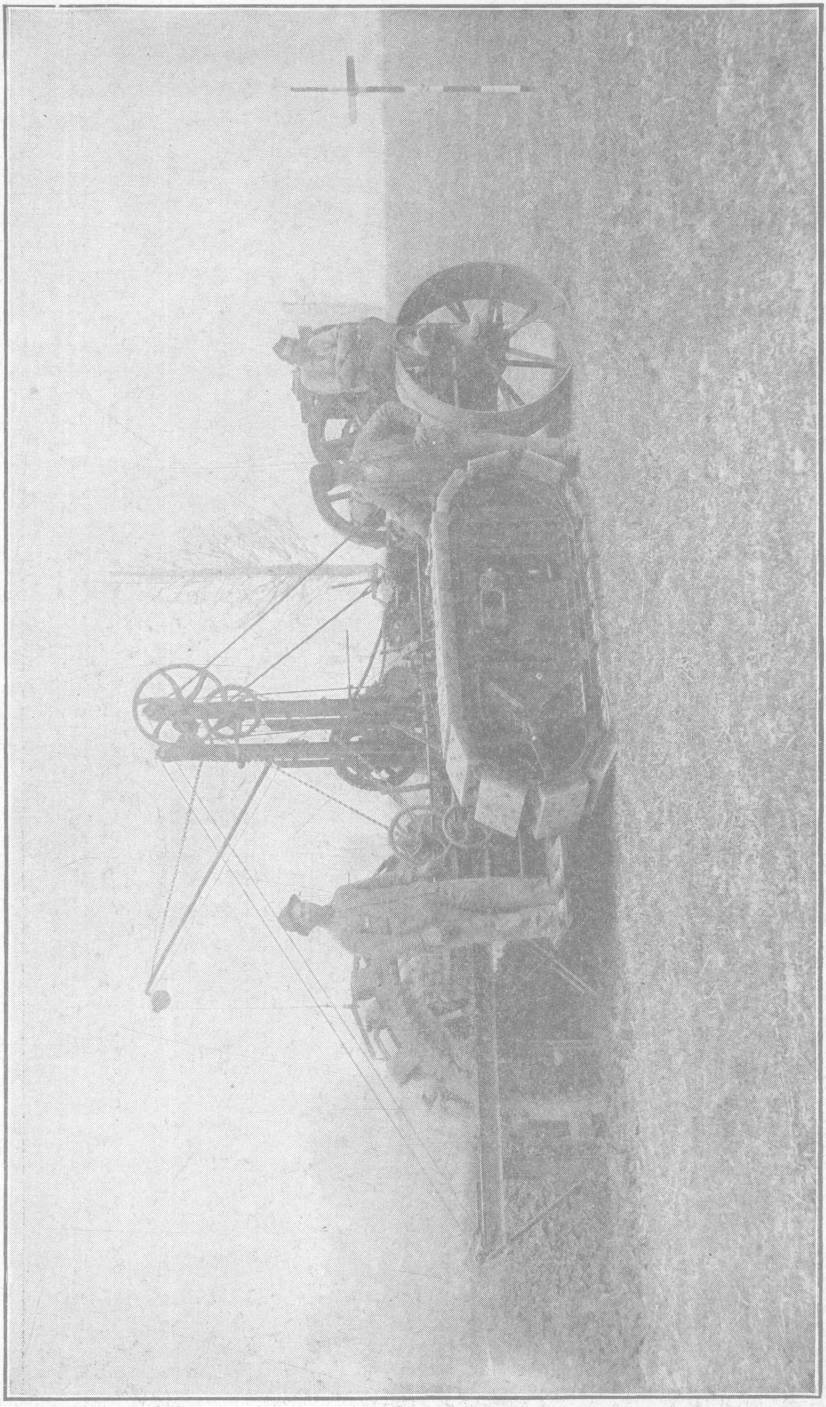


Fig. 5. Side view of traction ditching machine

TILING OPERATIONS IN 1910

In 1910 tiling operations were conducted on ten separate fields, covering twelve water sheds. Table II shows that seven of these fields were small, and as several operations were carried on simultaneously in them, it was not practical to keep the cost of each one separately. These contained 21 acres and included 216 rods of water pipe line, sewers and lines for hog barn disposal. The total area drained during the year was 65½ acres and a total of 4080 rods or 12½ miles was installed in that area.

TABLE II. Summary of tiling operations in 1910

Man rate, 15c per hour; horse rate, 10c per hour: machine operator, 20c per hour.

Operations	Field cost				
	Field 24	Field 29	Field 30	Seven misc' areas	Total
Areas in acres	29	10½	5	21	65½
Rods	1591	755	300	1434	4080*
Machine charges	$172.46	$ 81.84	$32.52	$155 41	$442 23
Machine operator	66.92	28.04	12.64	20.86	128.46
Gasoline	35.50	14.34	5.17	34.51	89.52
Oil	1.74	1.43	.64	2.06	5.87
Hauling tile	59 34	41.80	12.03	18.83	132.00
Contract laying tile	115.95	41.25	22.95	78.60	258.75
Filling ditches	52.08	28.40	5.16	17.12	102.76
Other equipment charges	6.17	3.05	1.20	4.58	15.00
Undivided operations	25.51	3.00	3.60	144.53	176.64
Cost of tile	325.95	132.16	79.47	297.42	835 00
Overhead charges	36.59	17.37	6.90	32.99	93.85
Plotting drains	25.13	11.93	4.74	18.88	60.68
Grand totals	923.34	404.61	187.02	825.79	2340.76

*12¾ miles

For the work this year a new power tile ditching machine, equipped with a gasoline engine, was purchased early in the spring and nearly all the trenching done during this season was with this machine. (See Figs. 4 and 5, pages 29-30.) One man was required to operate the ditching machine and another man to lay tile, although the tile layer occasionally assisted the machine operator in setting grade stakes, repairing the machine, etc. The main ditch was first installed and then the laterals were connected to it in a systematic manner. In connecting laterals to the main it was necessary to do some hand digging, because the machine could not be put to the proper grade nearer to the main ditch than 6 or 8 feet, depending, of course, upon the depth of the main. The cost of this necessary hand digging in connecting the laterals with the main ditches has been assembled with other costs in a column called "Undivided operations."

The largest field tiled during the year 1910 (No. 24, see Fig. 2 on page 28) contained 29 acres. In it 1591 rods of drains were installed, or an average of 55 rods per acre. During July, August and September the work was much interrupted because of using the men for harvesting and farm work.

This field, which was a heavy blue grass sod, with the exception of about 3 acres of muck swamp which usually was covered with water about half the year, had been used as a pasture for many years. The drains of this field had two outlets; the principle one being a twelve-inch tile leading to an open ditch. The fall of this main for the last 500 feet did not exceed one inch per one hundred feet. In general, however, the topography of the field was quite broken, affording plenty of fall. Indeed there were slopes in which the fall was as much as 8 feet to the hundred.

The second field of importance, which was drained in 1910, was a young orchard which had been set that same spring. There were 10½ acres in this orchard and in it a total of 755 rods of drain were installed, or 72 rods per acre. This greater amount of tile per acre was due to the fact that the trees were set 32 feet apart and that a line of tile was installed between each two rows of trees, whereas in other fields 40 feet apart for laterals was the distance more frequently used. The topography of this orchard field was rolling, but without abrupt breaks. The fall per hundred feet would run about 6 inches, although in a few instances there was a fall of three or four feet to the hundred.

It should be noted in passing that the wet weather in April, September and October, previously mentioned, interfered quite a little in the operation of the tile ditching machine, due to mud sticking to it.

TILING OPERATIONS IN 1911

During the season of 1911 tiling operations were confined to two fields, Nos. 5 and 31 (See Fig. 2 on page 28) with the exception of 198 rods in two other fields. In all 4755 rods of tile were installed in 122½ acres. Table III gives a summary of the work executed this year.

Operations were begun late in March and continued throughout the season until October 31st. The first work was done under very unfavorable conditions. It was the digging of a main ditch which followed the channel of an old open ditch, in which the cut in places was from 4 to 6 feet. The ground was so wet at this time of the year that slipping of the propeller was not infrequent and caving in

of the ditch greatly hampered the progress and necessarily increased the cost. In some places the soil where wet was such a waxy clay that it caused considerable trouble by sticking to the machine.

TABLE III. Summary of tiling operations in 1911.

	Field 5	Field 31	Misc. areas	Total
Area in acres	54	65	3½	122½
Rods	2666	1891	198	4755
Machine charges	$407.88	$289.32	$30.28	$727.48
Machine operator	95.10	72.00	19.16	186.26
Gasoline	66.00	69.48	9.72	145.20
Oil	7.84	4.34	.96	13.14
Hauling tile	63.10	94.94	12.50	170.54
Contract laying tile	184.98	121.33	20.11	326.42
Filling ditches	78.08	82.22	12.31	172.61
Other equipment charges	11.17	7.98	.89	20.04
Undivided operations	107.62	35.78	24.90	168.30
Cost of tile	567.00	726.85	61.34	1355.19
Overhead charges	61.32	43.49	4.56	109.37
Plotting drains	42.12	24.58	*	66.70
Grand totals	1692.21	1572.31	196.73	3461.25

Overhead charge is 2.3c per rod. Plotting drain charge is 1.58c per rod.
* Not plotted.

Ditching in field No. 5 began in April and continued throughout the summer until August 25th. As shown by the table, the area covered in this field is 54 acres, in which were installed 2666 rods of tile, making an average of 49 rods per acre. The general topography of this field is rolling. There were two swamps in it; one a cat-tail swamp full of brush and trees and another which covered about 2½ acres. A former owner had attempted to drain this latter swamp a number of years previously, but the attempt was unsuccessful. The soil in these swamps varied from a muck in their center to a heavy, black waxy clay around the outside. In a few places in this field stones were sufficiently numerous to retard the progress considerably but no serious breakage was occasioned.

One of the main ditches in this field is worthy of note. It is 830 feet long with an average depth of cut of about 6.5 feet. The maximum cut was 9.7 feet, which was maintained for a distance of about 300 feet. The machine was operated in this ditch to its maximum depth, which is 4½ feet, and the remainder was dug by hand, using contract labor. The total cost of extra labor on this ditch, after the machine had done its part, was $103.62, or an average of $2.06 per rod. If we add the cost of gasoline, oil and other machine charges, which amount to $10.44, to the other labor charges of $103.62 we have a total cost of $114.06, or $2.27 per rod, which is the installing cost of this main ditch. Approximately 266 cubic yards of earth were excavated in digging this ditch. This would make the cost of excavating 42.9 cents per cubic yard. From the foregoing it will be manifest that outlets are expensive when no natural outlet is available.

Tiling in field No. 31 began at the conclusion of work in field No. 5 and continued until the close of operations on October 31st. The area covered in this field was 65 acres. The field joind field No. 24, which was tiled in 1910 (See Fig. 2 on page 28). 1891 rods were installed in it, or about 29 rods per acre. The distance between laterals was greater in this field than in many of the others; varying from 50 to 110 feet, with an average dtstance of about 90 feet. Fully 35 acres of this field was a swamp, a portion of which had been farmed and nearly all of which had been previously drained. The drains, however, which had been installed from 30 to 35 years previously, had become useless.

Before anything could be done toward draining this field it was necessary to secure a satisfactory outlet. The excavation of this open ditch outlet, which was done by the farm teams and laborers, using slip scrapers, was started in the summer of 1910 and finished in October 1911, the work being prosecuted upon this ditch only at such times as men and teams were not required for farm work. The total length of outlet streams was 1.2 mile, which included about 500 feet of new cuts. When this ditch was finished the bottom of the outlet had been lowered fully 2½ feet. The cost of making this outlet was $558.18 and is not included in summary Table III.

In the ditching of this field a few round stones were encountered in the upland but no trouble or serious delay was experienced. Continued heavy rains during the late fall, as previously mentioned, caused considerable delay, especially in the muck portions. The muck became so full of water that it rushed in from the sides of the ditch so fast that the tile layer had to let the excess run away before he could lay the tile. A few rotted logs, buried beneath the surface in the muck portion of the field, interfered somewhat with the work.

CHARACTER AND COST OF TILE USED

The tiles used in all this work were ordinary, medium burned tiles, made from a good quality of clay. All tiles up to a diameter of 10 inches were in foot lengths, but 10-inch and larger sizes were in 2-feet lengths. The breakage of tiles through handling was not large, the maximum amounting to five or six feet per load of 1000 3-inch tiles. Even with this breakage the over-run amounted to from 3 to 6 percent, in other words 100 feet of tile paid for at the factory would lay from 103 to 106 feet in the ditch. The larger tiles seemed to have a greater over-run than the smaller ones. The cost of tile per acre for tile drains varies of course in accordance with the size of tile and the number of rods per acre. The average cost of tile per rod in the main fields in Table IV is 24.45 cents, and the cost per acre, with an average of 48 rods, is $11.72.

TABLE IV. Showing sizes and total cost of tile used

Field	Area	No. feet and size of tile							Totals		Per acre		Cost per rod
		3-inch	4-inch	5-inch	6 inch	8-inch	10-inch	12-inch	Rods	Cost	Rods	Cost	
No. 24	29	20721	2772	487	775	548	267	687	1591	$ 325.95	54.9	$11.24	$0.2049
No. 29	10½	10912	541	729	...	275	...	...	755	132.16	71.9	12.59	.1750
No. 30	5	3102	802	...	273	773	...	...	300	79.47	60.0	15.89	.2649
No. 5	54	37757	1010	2146	894	751	623	830	2666	567.00	49.4	10.50	.2127
No. 31*	65	13843	9241	2626	957	450	1825	2265	1891	726.85	29.1	11.18	.3843
No. 2	40	Various sizes not tabulated							2560	555.39	64.0	13.88	.2169
Totals....	203½	...	....	....	....	....	....	....	9763	2386.82	....	....	....
Averages...	....	....	....	....	....	....	....	..	..	.....	47.97	11.72	.2445
Small fields													
Misc' areas...	24½	....	....	....	....	....	....	....	1632	$358.76	66.62	14.64	.2198
Cost of tile per 1000 feet													
	....	$9.90	$14.85	$21.78	$29.70	$49.50	$74.25	$99.00	....	....	....	....	....

*405 feet of 13 inch tile were added to the 12 inch.

COST OF HAULING TILE

Table V furnishes a very good basis for estimating the time required for, and the cost of, hauling tile, especially when taken in conjunction with Table IV. Naturally, the cost of hauling tile would vary with the size of the tile, the length of the haul, and the cond tion of the roads. Favorable or adverse conditions in connectior with any one of these factors may affect the cost materially.

For example, in the case of fields Nos. 29 and 30, in which the haul and weight of tile were practically the same, the roads were so bad when the tile was hauled for field No. 29 that it cost 38 percent more per rod than it did for field No. 30. Again, in case of field No. 31, for which the haul was much shorter than for No. 29, and for which the roads were in good condition, the expense was much increased by the haul within the field, because it was necessary to haul much smaller loads, especially through the muck portions of the field. Ordinarily about the same sized loads were hauled on the road and in the field, but in the case of field 31 it was necessary to unload a part of the tile and make a second trip through the field.

TABLE V. Hours required for and cost of hauling tile

Man rate 15c per hour. Horse rate, 10c per hour.

Fields	Rods	Area	Distance of haul in miles	Conditions of roads	Totals			Per rod of tile		
					Hours		Cost	Hours		Cost
					Man	Horse		Man	Horse	
No. 24.....	1591	29	2½	Good	184.0	317.5	$ 59.34	.116	.200	$0.0373
No. 29.....	755	10½	3½	Bad	124.0	232.0	41.80	.164	.307	.0554
No. 30.....	300	5	3½	Good	35.5	67.0	12.03	.118	.223	.0401
No. 5.....	2666	54	1½	Fair	194.7	339.0	63.10	.073	.127	.0237
No. 31.....	1891	65	3	Good	275.0	537.0	94.94	.145	.284	.0502
Totals .. .	7203	163½	..	....	813.2	1492.5	271.21	....	....	.....
Av. per rod	....	....	..	....	....	.....	....	.113	.207	.0377

Had it been possible in all cases to haul tile at no other time than when the roads were good the cost of hauling could have been materially reduced, but in this work it seemed necessary to use the regular farm teams and to try to do the hauling when it was not possible to us the teams at other farm work. This hauling was done with heavy teams, weighing not less than 2700 pounds, and with wagons having 4-inch tires, thus enabling the handling of heavy loads regardless of the condition of the roads. 100 feet of 12-inch tile or 1000 feet of 3-inch tile were considered a load on good roads.

THE POWER TILE DITCHING MACHINE

The power tile ditching machine, in connection with which these data were obtained was equipped with caterpillar tractor (See Figs.

4 and 5, pages 29-30) the weight of the machine thus being distributed over a surface of about 24 square feet. This feature enabled the machine to be operated over very wet ground and in many instances to be run through swamps covered with water without having serious trouble from miring.

TABLE VI. Summary of hours and cost for machine operator

20c per hour for operator

Fields	Area	Rods	Totals		Per acre		Per rod	
			Hours	Cost	Hours	Cost	Hours	Cost
No. 24.....	29	1591	334.6	$ 66.92	11.54	$2.31	.2103	$0.0421
No. 29.....	10½	755	140.2	28.04	13.35	2.67	.1857	.0371
No. 30.....	5	300	63.2	12.64	12.64	2.53	.2106	.0421
No. 5.....	54	2666	475.5	95.10	8.81	1.76	.1784	.0357
No. 31.....	65	1891	360.0	72.00	5.54	1.11	.1904	.0381
Total	163½	7203	1373.5	274.70	....	....	.....	.....
Average....	....	....	.....	.....	8.40	1.68	.1907	.0381

Uneveness of the ground surface made but little difference in controlling the grade, as the operator had complete control over the machine at all times. In a few instances the depth of cut was changed from 4 feet through a knoll to half that depth within a distance on the surface of about the length of the machine, and in doing this a perfect grade was easily maintained.

The machine was equipped to do work at four different rates of speed, which were used according to depth of digging and stickiness of dirt. A higher speed would dig to a depth of two feet and with very favorable conditions even deeper at practically the same cost. The second speed was used in digging to a depth of 3 feet under ordinary conditions, and in some cases as deep as 3½ feet. The third speed would dig to 4½ feet in depth, which was the limit of the machine. The fourth or slowest speed was not used in connection with this work. Dry ground had no effect upon the machine except to cause the knives to need sharpening more frequently. Soil frozen to a depth of four inches caused but little trouble. Freezing of wet earth to the machine occasionally caused trouble but this was of little consequence. While in some cases, in the early spring or late fall when the ground was soaked full of water and was of a spongy nature, good progress could not be made because of the slipping of the propellers in the soft mud, yet during the greater part of the season the machine could be operated satisfactorily immediately after heavy showers. In most cases the machine was run only one way—from the main up the slope. However, at times when but little water came into the ditch the machine could be operated down the slope just as successfully. Round stones or boulders in the ditch line caused more or less trouble,

depending upon the location in the ditch, the size of the stones, etc. Usually boulders the size of a man's head could be removed by the machine with comparative ease, but when larger than this it was necessary to raise the digger wheel and remove them by hand.

HOURS AND COSTS FOR MACHINE OPERATOR

In Table VI, in which are are summarized data regarding the machine operator, it will be noted that the cost per rod varies from 3.57 cents to 4.21 cents, with an average cost of 3.81 cents.

TABLE VII. Summary of gasoline and oil costs

Field	Area	Rods	Total cost		Per acre		Per rod	
			Gas	Oil	Gas	Oil	Gas	Oil
No. 24.....	29	1591	$ 35.50	$ 1.74	$1.224	$0.0600	$0.0223	$0.0011
No. 29.....	10½	755	14.34	1.43	1.365	.1360	.0190	.0019
No. 30.....	5	300	5 17	.64	1.034	.1280	.0172	.0021
No. 5.....	54	2666	66.00	7.84	1.222	.1450	.0248	.0029
No. 31.....	65	1891	69.48	4.34	1.069	.0670	.0368	.0023
Totals.....	163.5	7203	190.49	15.99	.....	.....	.....	.....
Averages.....	.....	.....	.....	.....	1.165	.0977	.0264	.00221
Misc' area....	24½	1632	44.23	3.02	1.805	.1235	.0271	.00185

It should be noted, however, that these prices are figured at 20 cents per hour for operator. This was the price actually paid, but it was lower than that for which an operator could ordinarily be secured, because of the fact that the man used for this purpose was one of the regular farm workmen, who had a natural bent in that direction. Ordinarily the wage of the operator would run from 30 to 40 cents per hour, thus making the cost greater. In order to be able to operate a machine successfully a man should understand the principles of tile drainage, the running of grade lines, etc., and at the same time he should be handy with machinery.

GASOLINE, OIL AND GREASE COSTS

In Table VII is shown a summary of gasoline, oil and grease costs for the entire area trenched with the machine. The average price of gasoline per gallon was 13.3 cents in 1910 and 12 cents in 1911. Cup grease cost 6¾ cents per lb., and oil from 16 cents to 35 cents per gallon. The best grade of gas engine oil was used on the engine but a cheaper oil was used on chains, sprockets, etc. While this factor of the costs may seem somewhat small, yet 3 cents per rod cannot be ignored nor can we ignore the fact that the price of gasoline is advancing constantly.

TABLE VIII. Tiling machine charges. Depreciation, repairs and interest on investment

Total costs								
Year	Acres	Rods	Miles tile	Depreciation	Repairs		Int. on investment	Total
					Labor	Cash		
1910	65.5	4080	12.75	208.08	$50.74	$100.00	$81.60	$441.23
1911	122.5	4755	14.86	242.50	88.05	365.47	71.15	767.18

Per rod					
Year	Labor	Cash	Interest	Depreciation	Total av. cost
1910	$0.01240	$0.02450	$0.02000	$0.0511	$0.1079
1911	.01852	.07677	.01495	.0510	.1613
	Av. for two yrs..		. .	.....	$0.1368

TILING MACHINE CHARGES

In Table VIII is summarized the overhead machine charges for the two years within which the machine trenching was done. These charges are classified under four headings, as follows:

1. "Labor repairs" which included cost of labor, usually rendered by the machine operator, in connection with actual repair work on the machine. While of course there are many cases in which a half-hour's time or less was spent by the operator repairing the machine, these have not been separated from the operating charge. All periods of a longer time than one-half hour are charged to "Repairs" and are itemized in this summary.

2. "Cash repairs" includes all repairs for machine, such as bolts, sharpening of knives, batteries for engine, for which cash is paid.

3. "Depreciation" is a variable item, depending upon several influencing factors. In this table it has been figured at 5.1 cents per rod, although at best this charge must be an arbitrary one unless a machine is actually worn out. The number of miles of ditch a machine will dig during its lifetime depends upon the depth of digging; condition of soil as regards texture and freedom from stones; care given machine by operator, etc. In determining the arbitrary figure of 5.1 cents per rod it was assumed that the machine would be capable of digging 100 miles of trench within its lifetime. Some machines have dug over 200 miles of ditch. It will be noted, however, that even on the 200-mile basis the cost of depreciation per rod would be 2.55 cents and that the total machine charge would only be lowered from 13.68 cents to 11.13 cents, thus making this, comparatively speaking, a minor point. Depreciation is figured on an initial cost of the machine amounting to $1,632. This price, of course, may

vary from time to time. If no larger tile than 8-inch were to be installed it would probably be cheaper to buy a smaller machine, unless the ground to be trenched is somewhat stony. In this connection it is interesting to note that the repair charge, especially cash repairs, for the second year was almost three times as much per rod as if was the first year.

4. "Interest on investment," which was figured at 5 percent, decreases from year to year, as the initial price is cut down by the amount which is charged off annually for depreciation.

MACHINE TRENCHING COMPARED WITH HAND TRENCHING

In Table IX is shown a comparison between the costs of hand and machine trenching, so far as it is able to make such a comparison from the work done on this farm. It will be noted that the cost per rod of machine trenching varies from 30.5 cents to 39.8 cents, whereas the hand trenching cost is 44.9 cents. It should be noted, however, that in these averages, there are more than four times as many rods of machine trenching as of hand trenching. While the cost of machine trenching would, in most cases, be increased somewhat by a higher rate per hour for the machine operator, and probably would be increased by the cash repair charges, yet even with these increases it probably never would overcome the difference between machine and hand trenching, which, as shown by Table IX, is 7.4 cents.

TABLE IX. Comparison between hand and machine trenching.

Field	Acres	Rods	Total cost except tile and hauling	Per rod machine	Per rod hand
No. 2	40	2560	$1,149.30	.....	$0.449
No. 24	29	1591	538.05	$0.338	.....
No. 29	10¼	755	230.65	.305	.....
No. 30	5	300	95.52	.318	.....
No. 5	54	2666	1,062.11	.398	.....
No. 31	65	1891	750.52	.397	.....
Misc. areas	24½	1632	632.43	.388	.....
Totals	228	11395	4,458.58	.....	.....
Averages	...	.....	.....	0.375	0.449

While there may be conditions in the very early spring when the ground is thoroughly water-soaked which make the ditching machine not very satisfactory because of its slipping and of mud sticking to it, yet this is fully offset by the fact that it digs readily in dry weather even though the ground may be so hard that it is almost impossible to trench with a spade. It is very much easier to maintain a uniform grade when ditching with a machine than doing the work by hand. In the trenching which was done by hand in

1909 almost all of the ditches were tested with water before tile was laid. This is, of course, somewhat expensive, especially if the water is not near at hand. A fall of from four to six inches per hundred feet in the ditch line would, however, remove the necessity of testing with water.

One other point in favor of the ditching machine is the speed that can be made with it. By a comparison of Tables I, VI and X, it will be noted that the machine operators use less than one-sixth as much labor per rod in trenching and laying tile as is spent when the work is done by hand. Considering the scarcity of labor and the advancing wages that farmers are being forced to pay, it is evident that even though machine trenching were to cost more than hand trenching they probably would be forced to make use of the machine.

COST AND TIME REQUIRED TO LAY TILE

In Table X is summarized the cost of laying or installing 7,203 rods of tile upon 163½ acres. This includes placing the tile in the ditch and putting on just enough earth to hold it in place. For various reasons the tile layer is required to excavate by hand occasional short ditches, as for example, in finishing a ditch where the machine could not approach a fence as close as was necessary. In field No. 30 the larger "Tile laying cost" of 7.65 cents per rod is due to hand work of this character, which was not separated from the laying of the tile. From this summary table it will be noted that the cost varied from a minimum of 5.46 cents to a maximum of 7,165, and that the average is 6.75 cents per rod. It will also be observed that one man installed on the average almost 45 rods of tile per day.

TABLE X. Showing hours and costs for laying tile.

Wages, 30c per hour						
Field	Acres	Rods	Totals		Per rod	
			Hours	Cost	Hours	Cost
No. 24.	29	1591	386.5	$115.95	.243	$0.0729
No. 29..... ...	10½	755	137.5	41.25	.182	.0546
No. 30.	5	300	76.5	22.95	.255	.0765
No. 5	54	2666	616.6	184.98	.231	0693
No. 31.....	65	1891	404.4	121.32	.214	.0642
Totals..... ..	163½	7203	1,621.5	486.46	....	.....
Averages..... ..	....	....	.....	.....	.225	0.0675

Owing to the very great importance of having the tile laid properly it is usually deemed advisable to secure for this purpose the services of an efficient man who makes tiling his business. The services of such a man are always in demand and consequently a higher price per hour must be paid to secure him.

In Table XI is summarized the cost of filling the ditches for 7,203 rods of tile installed in 163½ acres. From this table it will be noted that the cost per rod of filling ditches varies from 1.72 cent to 4.4 cents and that the average is 3.43 cents. It will also be noted that two men with a team can on the average fill 140 rods of ditch per day.

TABLE XI. Hours and costs for filling ditches.

Man rate, 15c per hour; horse rate, 10c per hour.

Field	Fields		Totals			Per rod		
			Hours			Hours		
	Area	Rods	Man	Horse	Cost	Man	Horse	Cost
No. 24	29	1591	208.70	207.8	$52.08	.1312	.1307	$0.0327
No. 29	10½	755	131.40	87.0	28.41	.1740	.1152	.0376
No. 30	5	300	21.07	20.0	5.16	.0702	.0666	.0172
No. 5	54	2666	319.50	302.0	78.13	.1198	.1132	.0293
No. 31	65	1891	333.50	332.0	83.23	.1764	.1756	.0440
Totals	163½	7203	1,014.17	948.8	247.01	.....	.....	.....
Averages	...	....	.....	.....	.....	.1408	.1317	.0343

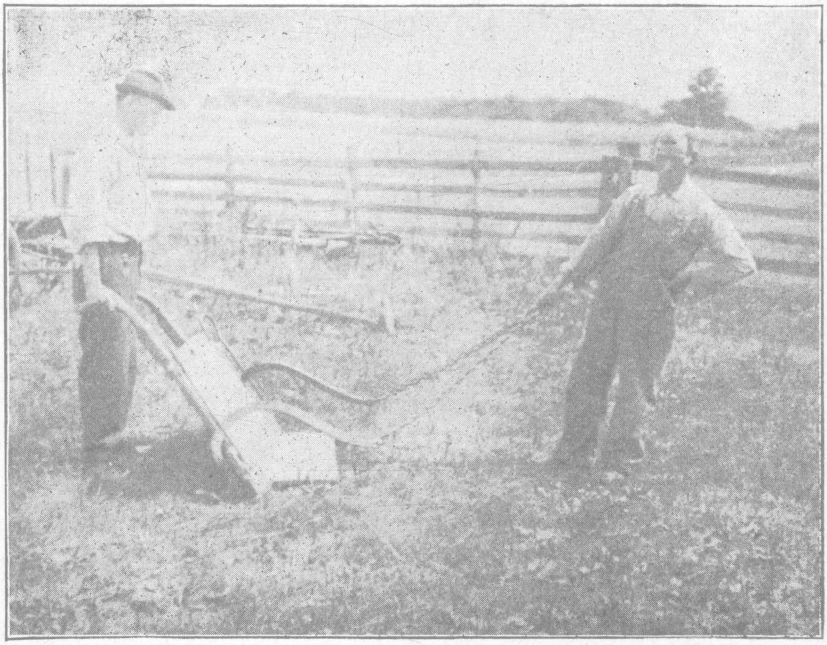


Fig. 6. Special scraper for filling ditches.

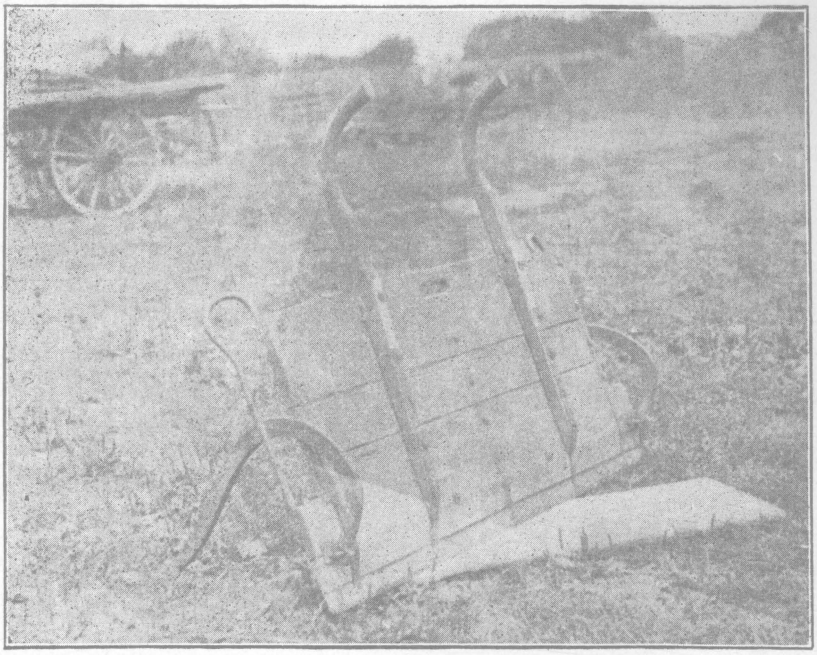


Fig. 7. Special scraper for filling ditches.

The cost of filling ditches varies with the condition of the soil and the depth of the cut. It was found advisable to fill the ditches soon after trenching, because they could then be filled about one-fourth faster than if allowed to remain open during a heavy rain storm. The rain packed the soil and made filling much more difficult for both men and team.

A heavy team was used with a specially prepared scraper about 4 feet long, which consisted of a straight board with a steel cutting edge and had a hitch so constructed that when the team pulled taut at right angles to the ditch and the operator bore down on the handles the scraper would move into the ditch all the dirt thrown out on one side of it. (See Figs. 6 and 7, pages 42-43.) It was, of course, necessary to back up the team and move the scraper longitudinally along the ditch for each scraper full. This method was found to be more satisfactory than the use of a plow or a large township road scraper.

PLOTTING DRAINS

The maps or plots of the several drainage systems were made by county surveyors after the system was installed. (See Figs. 2 and 3.) The charge for this operation includes the engineer's time,

expenses in the field and in plotting and blue printing. It was not deemed necessary or advisable to make a plot of a system before installing, but after installing it was thought wise to have such a map for the purpose of affording a ready reference for the location of drains in case of trouble with the system.

TABLE XII. Recapitulation of installing costs per rod.

	Hand work 1909	Machine 1910	Machine 1911	Average machine
Area in acres	40	65½	122½	....
Number rods	2560	4080	4755	....
Machine charges	.....	$0.1084	$0.1529	$0.1324
Machine operator	.....	.0315	.0392	.0356
Gasoline	.....	.0219	.0305	.0266
Oil	.....	.0014	.0028	.0022
Contract laying	*$0.376	.0634	.0686	.0663
Filling ditches	.030	.0252	.0363	.0312
Other equipment charges	.004	.0037	.0043	.0040
Undivided operations	.....	.0433	.0354	.0380
Overhead charges	.023	.0230	.0340	.0230
Plotting drains	.0158	.0149	.0140	.0144
Averages	0.4489	0.3367	0.4071	0.3746

*Includes trenching.

In Table XII is given a summary of the preceding tables as regards all tiling operations except hauling, which, in accordance with Table IV, may be figured at about 4c per rod. The cost of tile will vary with size of tile used and other factors, but Table IV will assist in making an estimate of such cost in the absence of figures from the factory. From the foregoing pages it will be manifest that had the trenching for all the 11,395 rods of tile referred to in this circular been done by machine the total cost of tile and installation would have been about two-thirds of a dollar per rod, and that with the fifty rods per acre used on this farm, three acres would have cost about one hundred dollars.